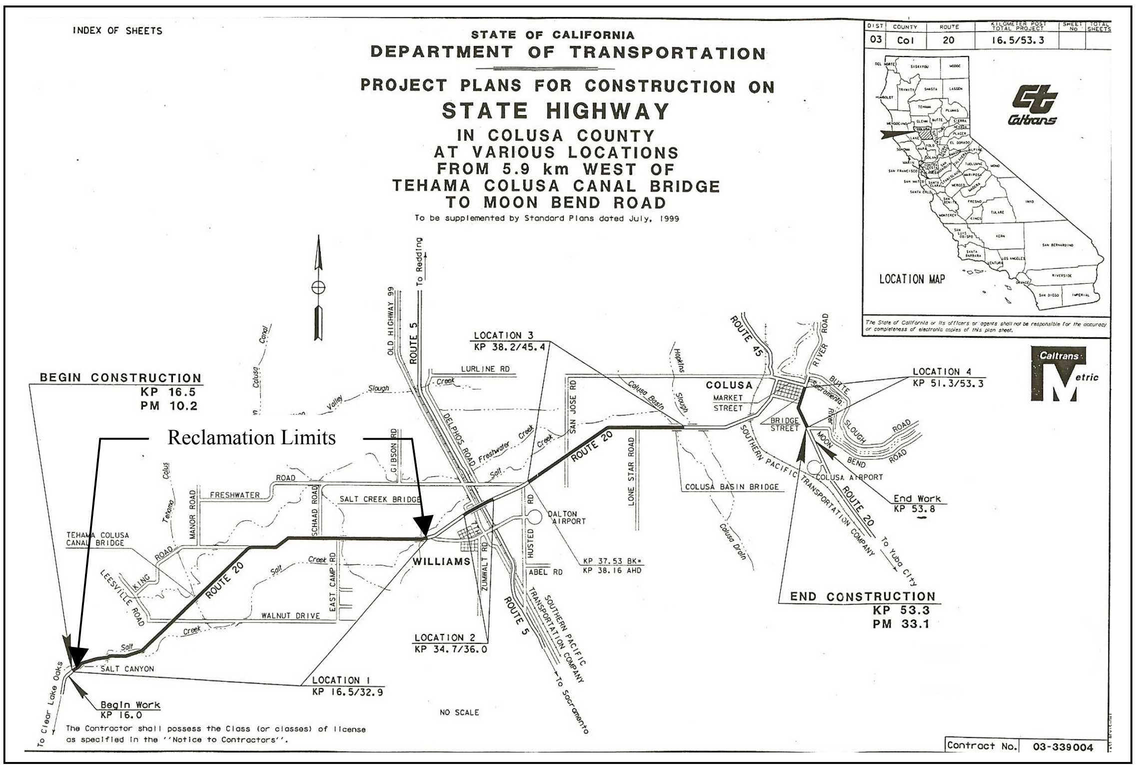
FINAL COMPLETION REPORT For

COLD FOAM IN PLACE RECLAMATION Col-20 PM 10.2-28.2



North Region Materials
Marysville, CA
August 2006

BACKGROUND:

This portion of Col-20 was defined as a state route in 1919 and signed as Highway 20 in 1934. Highway 20 is considered the main route between Highway 1 on the coast and Highway 80 inland. The original configuration was a non- engineered dirt road. The first paving occurred in 1918 and consisted of portions of the roadway being paved with concrete. The original pavement consisted of approximately 14 to 16 feet of concrete, 0.46' thick. Over the years the concrete has been overlaid with hot mix asphalt (HMA), removed and replaced with granular base and HMA, widened and rebuilt.

The area ranges in elevation from 59 feet at Williams to approximately 115 feet at the western boundary of the project. A summary of climate data is shown below:

Rain Days	93
Average Annual Rainfall	15.64"
Highest Rainfall on Record	38.22"
Lowest Rainfall on Record	8.02"

Over the years farming has occurred on both sides of the highway. Crops range from rice to cotton to orchard. Much of the irrigation is done through flooding of fields. With this, farming fields have built up in elevation. In many places the roadway elevation is lower than the surrounding farm fields. During periods of heavy rainfall water is often over the pavement. Because of this flooding and the need for the roadway to be accessible the elevation of the roadway has been raised in different locations over the years.

Due to drainage problems it was determined that the existing pavement profile could not be raised between post mile 28.2 and approximately 12.0. This created a dilemma for the project designers, as no detours were available and because the roadway is one of only two northern California routes to the coast, it had to remain open to traffic. Because of the poor condition of the roadway, a simple grind and replace strategy could not be utilized, rather the roadway needed to be rebuilt. Conventional construction methodology would have required a minimum of three construction seasons and extended one way and some potential 24-hour traffic controls.

In October 2002 the North Region Materials Branch, Marysville requested from the Pavement Design and Rehabilitation Committee (PDRC)[1] that the segment from post

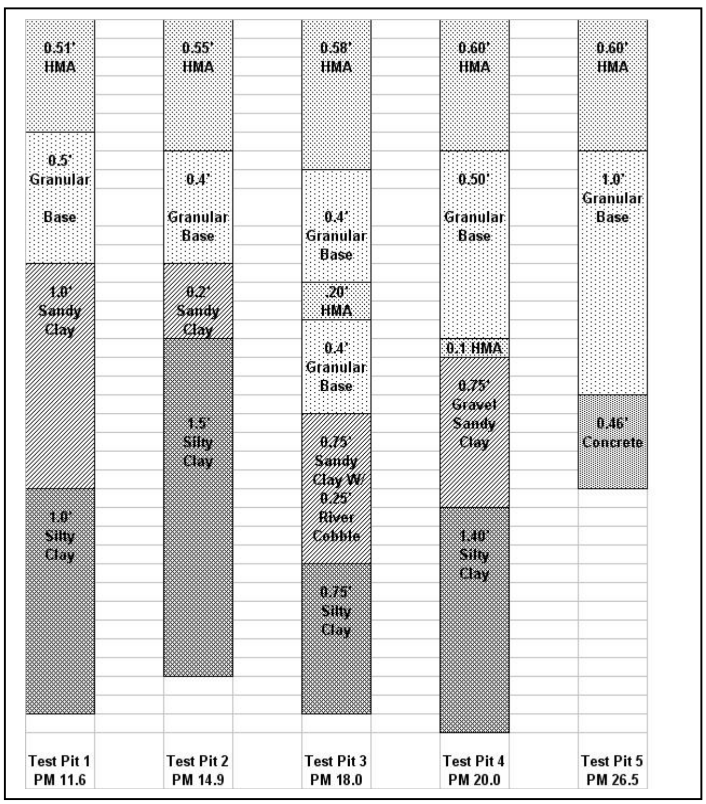
[1]Memorandum to PDRC October 12, 2000

mile 10.2 to 28.2 be considered for a pilot project utilizing full depth reclamation as a way to rebuild the roadway in place. The proposal showed that the entire segment could be rebuilt in significantly less than one construction season, with minimal impacts to traffic. In December of 2000 the PDRC granted permission to develop plans and specifications for bid for the full depth reclamation of Highway 20 west of Williams. The project design was accomplished utilizing the "Capital Preventive Maintenance Program" (CAPM).

ENGINEERING ANALYSIS:

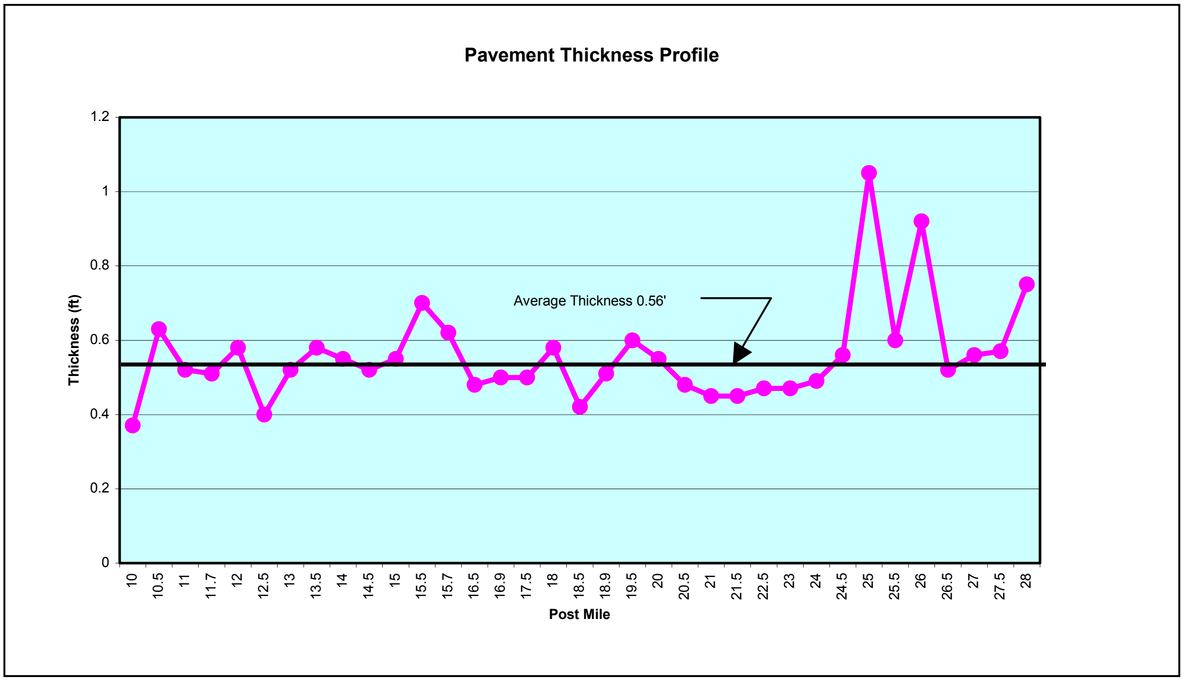
In early 2000 investigations were carried out by North Region Materials Branch, Marysville and AA Loudon & Partners, Consulting Engineers, Kloof, South Africa. The scope of the investigation was a detailed visual inspection, five test pits to determine existing structural section and native material. Test pits showed silty clay as a native material, a sandy clay that may have been imported, or was the result of farming operations at the turn of the century, granular base and HMA. All test pits showed contamination of upper layers with lower layer material. Test Pit data is shown below:

Test Pit Profiles



A total of 37 cores were taken to provide a pavement thickness profile and provide access points for a Dynamic Cone Penetrometer (DCP) The DCP was used to determine in-situ strength of the existing base and native material.

The average HMA thickness was 0.56', with a standard deviation of 0.13 with most cores showing a granular base below the HMA. Pavement profile is shown below:



DCP penetrations were recorded at test pits to determine in-situ strength characteristics of material, and to use as a comparison / correlation for other segments of the route within in the reclamation area. With the exception of one area, DCP penetrations per strata for test pits matched DCP penetrations per strata with in the vicinity of the test pit. The one exception was at PM 17.5 EB. The DCP reading showed no difference in penetration from bottom of HMA to 3.0 feet in depth. Average values are shown below:

DCP Penetration			
Material	Granular Base	Sandy Clay	Sandy Silt
Average Pen/5 blow	40mm	71mm	90mm
PM 17.5	310mm	296mm	+293mm

R-Value analysis of material taken from test pits 2 and 4 gave the following values:

R-Value			
Test Pit	R-Value Base	R-Value Sandy Clay	R-Value Silty Clay
#2	70	45	5
#4	78	40	Less than 5

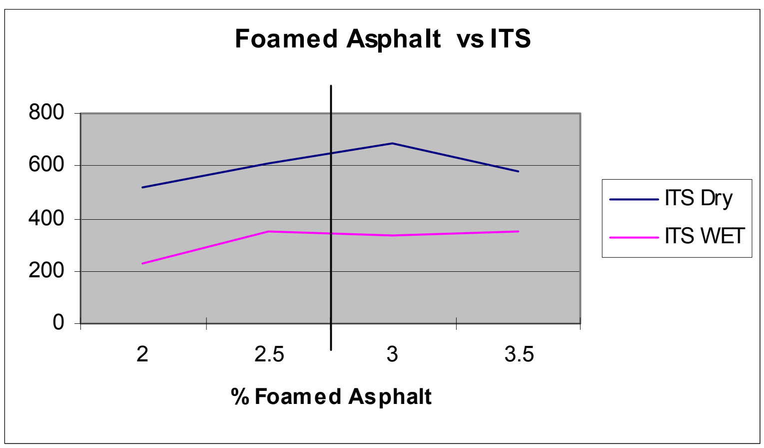
R-Values shown are expected for this portion of the valley.

Cold Foam Mix Design:

A foamed asphalt mix design was done utilizing AR4000 Huntway oil, a WLB-10 foam machine and a Hobart mixer. Optimum moisture for foaming was determined to be 2.4% water by weight of the bitumen. Based on a blend of 40% asphalt and 60% existing base plus 1.5% cement as a mineral filler to increase fines content, briquettes were fabricated and tested Results are shown below:

Foamed Mix Design Results				
Foamed Asphalt	2.0	2.5	3.0	3.5
Bulk Density (kg/m3)	2168	2222	2211	2176
ITS Dry (kPa)	521	612	683	582
ITS Soaked (kPa)	231	347	338	352
Ratio % Dry/Soaked	44	57	50	61

Based on the above the recommended foamed bitumen content was selected as 2.5%, +/- 0.5%, and 1.5% cement.



Structural Section Design:

For this design it was assumed that the foamed asphalt would be as strong as an asphalt treated base. A gravel factor of 1.4 was assigned to the material. Based on a Traffic Index of 9.0 the required structural section[2] was:

Remove 80 mm existing AC
Recycle 230 mm-existing AC and Base with 2.5% foamed asphalt & 1.5% cement

---

[2] Materials Recommendation; dated October 4, 2000

Place:

18mm OGAC
50mm DGAC Type A 19mm
68 mm Total

CONSTRUCTION:

In July 2001, construction began on the project. The prime contractor was Baldwin Construction and the recycling contractor was Western Stabilization. All testing done on the recycled material was performed by Caltran's North Region Materials, Marysville. Two recycling trains were used for this project. By utilizing the two trains, one lane could be recycled in one pass. This also minimized the ingress and egress of construction trucks into the traffic control. All recycling was done during daytime closures with one-way traffic control.

Two recycling trains were utilized. One recycling train consisted of:

3000-Gallon Bitumen Truck.
10' Recycler with foam bar.
3000-Gallon Water Truck.
One Vibratory Pad-Foot Roller
One Motor Grader
One Tandem Axle Steel Drum Roller
One Pneumatic Tired Roller

The second recycling train consisted of:

- 3000-Gallon Bitumen Truck.
- 8’ Recycler with foam bar.
- 3000-Gallon Water Truck.
- One Vibratory Pad-Foot Roller
- One Motor Grader
- One Tandem Axle Steel Drum Roller
- One Pneumatic Tired Roller

Recycling began at PM 20.0 heading westbound in the westbound lane. The pavement was recycled together with foamed oil and cement. The pads foot roller would then make an initial pass to compact the uncompacted material between the wheels of the recycler and back drag to level out the material. The pad foot would then continue until the roller walked itself out of the material, approximately three coverages. Next, the grader would cut the material to rough profile and cross slope but leave it about 1” high. The steel drum roller would then make three coverages with the vibratory on. The grader would come back in and cut the material to desired profile by hanging the blade on the centerline of existing and setting the blade to the desired cross slope. One final coverage with the steel drum roller, with the vibratory off, to iron the finish.

A water truck would then give a heavy spray of water as the pneumatic tired roller worked the water in to the recycled material, approximately three coverages. This would bring some fine material to the surface to give a smooth finish. A final sweeping and the compacted, recycled material was ready for traffic.

The recycled material needed to cure for a minimum of two days before placing the HMA overlay. The 45-mm HMA overlay of the westbound lane began at PM 20.0 when the recycling of the westbound lane at PM 10.3 was completed. The train then began recycling the eastbound lane at PM 10.3, heading eastbound. When the eastbound recycling was complete at PM 20.0, the HMA overlay of the eastbound lanes began at PM 10.3.

Sweeping to remove any loose material was required prior to releasing traffic on the recycled material. Each recycled segment was lightly watered three to four times a day for at least two days. After the first night of traffic running on the recycled material, it was determined that sweeping the day after a segment was recycled would also be required. This resulted in no windshield breakage claims.

"35 MPH" and "Pavement Ends" signs were positioned at each end of the recycle portion of the project. Additional "35 MPH" signs were needed throughout the recycled portions to remind motorists to reduce their speed.

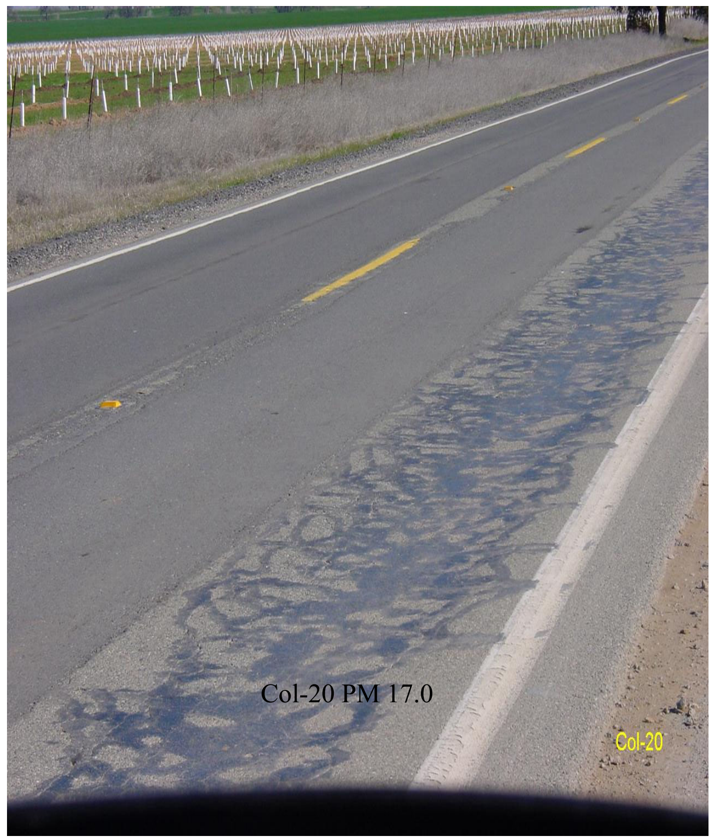
Each day would start with a two-mile closure. Because the material could be trafficked immediately, the closures were reduced as the day's recycling was completed. The closures were down to one-quarter mile by the end of the shift reducing the time to clear the traffic queues to less than ten minutes.

The recycling production averaged 2 miles per day. The entire twenty- lane mile project was recycled and paved in fifteen working days.

The final structural section as constructed was:

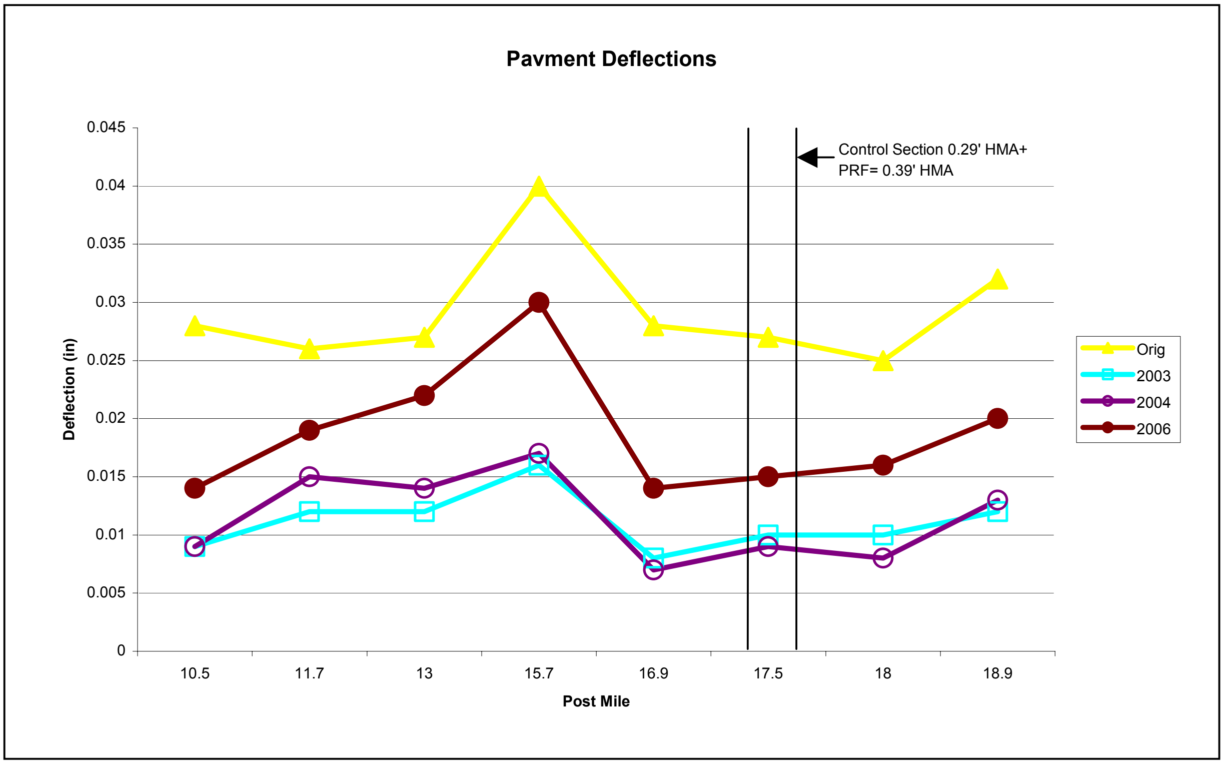
25-mm OGAC
45-mm DGAC
225-mm CFIPR
295-mm Total

POST CONSTRUCTION TESTING:



Post construction testing consisted of a detailed field review every 6 months and four deflection studies. Field investigations showed no visible distress for the years 2001-2005. Pavement was intact, with no signs of fatigue or thermal cracking. The maintenance crew reported one lateral crack developing at PM 11.2 in 2005 in the west bound lane. Upon investigation the crack was the result of embankment slippage and loss of lateral support. In July of 2005 another distressed area was identified at PM 17.5 in the eastbound direction. This distressed area coincided with an area that had no base under the HMA and as can be seen in the deflection graph below had the highest deflection of the project. The maintenance crew for the area indicated that the area around PM 17.5 was prone to yearly failures in both directions and wheel paths. At the time of preliminary testing and design, it was assumed that this segment would only last a maximum of two to three years, before remedial work would have to be accomplished.

Deflection studies were conducted in 2000, prior to project starting, then again in 2003, 2004 and 2006. Deflection readings were taken in approximately the same location (+/- 200 feet) and lane for all of the studies. As can be seen by the chart below, the highest deflections within the reclamation area occurred at post mile 17.5. This coincides with DCP readings for the area. Statistically, there were little to no changes between 2003 and 2004. Between 2004 and 2006, the average change in deflection was 0.007 inches with a standard deviation of 0.0027. This deflection increase coincides with a record number of rain days for the 2005 rain season. California saw many road failures from the 2005 winter rains. This pavement, despite the rain and high water table, has performed well.



Under current rehabilitation guidelines based on 0.15 feet of HMA, and a Traffic Index of 9.0, the allowable deflection is 0.24 inches. Using the data from 2006 the average deflection was 0.018, with the 80th percentile being 0.020 inches, which is well under the allowable deflection.

Photos, taken from approximately the same vantage point (14% super elevation) just prior to reclamation and then again in 2004 and 2006 show the pavement performing well, with no signs of lateral displacement of the HMA mat, or any longitudinal cracking of HMA or stabilized base.

CONCLUSION:

After five years the project is performing better than expected. The project was constructed utilizing the CAPM funding program. Guidelines for the CAPM require that the design life be 5 years. Other projects that have been constructed utilizing conventional methodology typically have some remedial work done at the 3-year point including such things as crack sealing and minor repairs. To date, no maintenance activities have been performed on the Highway 20 rehabilitated pavement. The one distressed area at PM 17.5 had a life expectancy of 2-3 years based on subgrade problems prevalent in the area (no base material, HMA over a silty/sandy saturated clay). Distress did not show until year five. This gave approximately twice the life than expected. Detailed investigations by Marysville Materials staff in July of 2006 showed no signs of thermal cracking, or other distressed areas.

This project should be considered a success for the following reasons:

- It has exceeded its design life and is performing very well.
- During the design life, no maintenance activities have been required.
- The roadway was rebuilt in place with minimal impacts to traffic.
- The roadway was rebuilt in less than one season, conventional methodology would have required multiple seasons.
- The reclamation process utilizes fewer ingress/egress of construction vehicles, making it safer for works and the public.
- 100 percent of existing roadbed material was recycled. This conserves natural resources.
- The project was accomplished for approximately the same cost as a grind and place 0.25 feet of HMA, yet by recycling to the bottom of HMA all reflective cracking and base soft spots were virtually eliminated.

RECOMMENDATION:

Finalize current pilot Special Provision, and make Standard Special Provision.
Publish project selection criteria and design guidelines full depth reclamation.
Publicize to Caltrans Design that Recycling and Reclamation are effective ways of rehabilitating old pavements.

For further information, please contact Joseph F. Peterson, P.E. at 530.741.5378

Attachment A

Memorandum to PDRC

MEMORANDUM

To: MR. KEVIN HERRITT, CHAIR
Pavement Design and Rehabilitation Committee

Date: March 1, 2000
File: 03-Col-20 KP 10.3/31.0
03-317-33900
PM 6.39

From: DEPARTMENT OF TRANSPORTATION
North Region - Construction

Subject: Approval to use Cold Foam Recycling

As you know the Department now uses the HA-22 Capital Preventive Maintenance Program (CAPM) to extend the life of segments of roadway that are or will be coming up for Rehabilitation under the HA-22 program. This programs utilizes guidelines that limit overlay thickness to 75 mm dense graded asphalt concrete (DGAC) and 18 –25 mm open graded asphalt concrete (OGAC).

One of the many obstacles that we face is ever increasing Traffic Indexes (TI's) in combination with deteriorating roadways. Deflections tend to be high when measured with the departments Dynoflect machines on distressed pavements, causing designed overlay thickness to be greater then 75 mm.

This project, Highway 20 from KP 10.3 to 31.0 is such a roadway. It is a two-lane facility that ranges from urbanized (City of Colusa) to open road. It has three distinct sections

- Urban area within and around the City of Colusa: This area is fairly well drained, has a pronounced crown and pavement distress is directly related to asphalt aging and trench encroachments.

- Valley Section: This area is flat with little to no drainage. The finished elevation of this roadway is often lower then the surrounding fields (Rice), and during flooding conditions is often under water. Pavement distress is continuous and is comprised of severe alligatoring and rutting in both wheel paths with pumping.

- Hilly Section: This area rolling hills and is fairly well drained. Pavement distress is directly related to asphalt aging.

Deflections ranged from a low of 0.127 mm over PCC to a high of 0.940 mm. with the average being 0.20 mm. Asphalt concrete thickness ranged from 137 mm to 320 mm, with the average thickness being 170 mm.

In addition to the high TI and deflections a large portion of this roadway KP 15+/- to KP 25+/- cannot have it's profile increased do to the water damming effect that it would cause additional flooding of property adjacent to the roadway.

Current design strategies call for milling off existing OGAC and placing overlays and reconstructing as follows:

MAINLINE – Existing: TI=9.0

Overlay OGAC/DGAC	18 mm (OGAC 9.5 mm)
	75 mm (DGAC 19mm Type A)
	93 mm Total

MAINLINE - New Structural Section: TI=9.0
(Required to hold profile)

18 mm (OGAC 9.5 mm)
90 mm (DGAC 19mm Type A)
PRF
45 mm (DGAC 19mm Type A) Leveling Course
225 mm AB (Class 2)
330 mm AS (Class 2)
708 mm Total

SHOULDERS - New Shoulder Section: TI=6.0
(Required to hold profile)

90 mm (DGAC 19mm Type A)
135 mm AB (Class 2)
210 mm AS (Class 2)
435 mm Total

This combination of problems leads it away from conventional 5 year CAPM strategies, and toward something that could take advantage of the in place material. The District feels if we could stabilize the existing AC and base, we could extend the life of the pavement a minimum of five years. To accomplish this we would like to try a test with "Cold Foam In-place Recycling. This process and associated materials are not proprietary.

The benefits of "Cold Foam In-place Recycling" are as follows:

- Structural Integrity: This process produces a thick bound layer. We believe that the gravel factor of this layer is between 1.4 and 1.7.
- Subgrade is not disturbed.
- Shorter construction window required then full construction.

Our proposal is as follows

Urban and hilly segments: Recycle 225 mm of AC and base, utilizing 3% foamed bitumen and 1% cement. Cap with 50 mm of DGAC

Valley Section: Mill off 50 mm of AC, recycle 250 mm of AC and base, utilizing 2% foamed bitumen and 15% bag house dust (-200). Cap with 50 mm of DGAC.

As can be seen there is significant difference between our current strategy and what is proposed through "Cold Foam In-Place Recycling". Some of the significant benefits are the reduced construction time (no gutting, detours or K-rail is required), reduced traffic impacts (no detours, shorter delays during construction) and improved safety aspects (no K-rail, or large drop off).

Headquarters Maintenance (Mr. Tom Pyle) supports this test project, and has stated funds are available.

Attached is a proposal by A A Loudon and Partners and Wirtgen GmbH for rehabilitation of Highway 20.utilizing the "Cold Foam In-place Recycle" process for your review and approval. Upon approval we would refine the proposal and specification and implement.

If you have any questions, or I my be of any assistance in this matter, please do not hesitate to contact me at (530) 741-5378.

JOSEPH F. PETERSON
District Materials Engineer

CC: Ray Tsztoo (PDRC)
Julia Rockenstein (D-3 Mat)
Tom Pyle (METS Concrete)
Sergio Colacevich (Design South)

Attachment B

Structural Section Recommendation

MEMORANDUM

To: MR. GERRY WONG, Chief
Design Branch, S4

Date: October 4, 2000
File: 03-Col-20
KP 16.6/45.1,51.2/53.3
PM 10.3/28.0,31.8/33.1
03-339001

Attn: Sergio Colacevich

From: DEPARTMENT OF TRANSPORTATION
District 3 - Materials Branch

Subject: **Updated Structural Section Recommendation**

This project is a two-lane facility that ranges from urbanized (City of Colusa) to open road. The five-year TI is 9.0. Deflections ranged from a low of 0.178mm (over PCC) to a high of 0.940mm, with an average of 0.200mm. The average AC thickness is 170mm. In addition to the high TI and deflections for this roadway, a large portion of the project cannot have the profile raised due to the damming effect that could potentially cause flooding of property adjacent to the roadway. This combination of problems leads this project away from conventional CAPM strategies. This updated recommendation is to utilize a “Cold Foam In-Place Recycling” process for a portion of the project as a test of this method of roadway rehabilitation.

STRUCTURAL SECTION RECOMMENDATIONS

MAINLINE **TI=9.0**

PM 10.3 to PM 17.4

Mill off 70mm of existing AC. Recycle 230mm of AC and base together with 2.5% foamed bitumen and 1½ % cement (by mass). Cap with the following:

18mm OGAC (9.5mm)
50mm DGAC (Type A, 19mm)
68mm Total

PM 17.4 to PM 17.6 (Control Section)

Mill off 95mm of AC. Dig out and repair areas of localized failures identified by rutting greater than 12.5mm and/or loose and spalling pavement and seal all cracks wider than 5mm. Place DGAC and OGAC overlays as shown below.

18 mm OGAC (9.5 mm)
75 mm DGAC (Type A, 19mm)
93 mm Total

PM 17.6 to PM 20.5

Mill off 80mm of existing AC. Recycle 230mm of AC and base together with 2.5% foamed bitumen and 1½ % cement (by mass). Cap with the following:

18mm OGAC (9.5mm)
50mm DGAC (Type A, 19mm)
68mm Total

PM 20.5 to PM 23.3

This section is in good condition with some thermal and reflective cracking. The deflections are within tolerable readings. Recommendation is to do nothing.

PM 23.3 to PM 28.3

Remove 95mm of existing AC. Conduct a field review and locate areas of severe failure identified by rutting greater than 12.5mm and/or loose and spalling pavement. Dig out and repair the identified areas of localized failures and seal all cracks wider than 5mm. In areas where base failure is prevalent due to high ground water, place PRF prior to placing overlay. PRF should overlap effected area a minimum of 600mm. Place DGAC and OGAC overlays as shown below.

18mm OGAC (9.5mm)
75mm DGAC (Type A, 19mm)
93mm Total

PM 32.1 to PM 32.7

Remove 75mm of existing AC. Conduct a field review and locate areas of severe failure identified by rutting greater than 12.5mm and/or loose and spalling pavement. Dig out and repair the identified areas of localized failures and seal all cracks wider than 5mm. Place DGAC overlay as shown below.

75mm DGAC (Type A, 19mm)
75mm Total

PM 32.1 to PM 32.7

Remove existing OGAC. Conduct a field review and locate areas of severe failure identified by rutting greater than 12.5mm and/or loose and spalling pavement. Dig out and repair the identified areas of localized failures and seal all cracks wider than 5mm. In areas where base failure is prevalent due to high ground water, place PRF prior to placing overlay. PRF should overlap effected area a minimum of 600mm. Place DGAC and OGAC overlays as shown below.

18mm OGAC (9.5mm)
75mm DGAC (Type A, 19mm)
93mm Total

GENERAL NOTES

Asphalt surfacing to be delayed until moisture content of the recycled material is 2% or more below the optimum moisture content.

OGAC shall extend beyond the ETW by 600mm on both sides. For areas of super elevation, OGAC shall be placed to EP on high side only. If rumble strips are to be constructed, OGAC shall extend only 300mm beyond the ETW.

Placement of the PRF should be as low in the DGAC as possible, but should be placed on a minimum 45 mm DGAC leveling course such that the top of the leveling course is on the same plane for the structural section of each lane.

MATERIAL SPECIFICATIONS

Open Grade Asphalt Concrete (OGAC) – 12.5 mm, shall conform to Section 39 of the Standard Specifications.

Dense Grade Asphalt Concrete (DGAC) –Type A, 19 mm Maximum Medium shall conform to Section 39 of the Standard Specifications and the Special Provisions.

Pavement Reinforcing Fabric (PRF) – Shall conform to Sections 39 and 88 of the Standard Specifications.

Asphalt Binder (DGAC) – Asphalt binder used for DGAC shall be grade AR-4000 and shall conform to Sections 39 and 92 of the Standard Specifications.

Asphalt Binder (OGAC) – Asphalt binder used for DGAC shall be grade Pba-1 and shall conform to Sections 39 and 92 of the Standard Specifications.

Paint Binder – Shall conform to Sections 39 and 92 of the Standard Specifications.

Prime Coat – Shall conform to Sections 39 and 92 of the Standard Specifications.

Shoulder Backing – Shall conform to SSP 19.33_M and the supplemental Grading and Quality Requirements.

Should you have any questions or require further assistance, please contact me at (ATSS) 457-5378 or contact Julia Rockenstein at (ATSS) 457-5176.

/s/ Joseph F. Peterson

JOSEPH F. PETERSON
District Materials Engineer

c: File